Improving Students' Collaboration and Communication Skills through Project-Based Digital Learning in Plantation and Herbal

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ABSTRACT

This study investigates the effectiveness of Project-Based Digital Learning (PBDL) in improving vocational students' collaboration and communication skills in the processing of plantation and herbal commodities. The research was motivated by the persistent lack of student interaction and the dominance of conventional teacher-centered instruction in vocational education, which hinders the development of 21st-century skills. Employing a quasi-experimental approach with a nonequivalent control group design, the study involved 108 students and 4 teachers from four vocational high schools offering Agribusiness of Agricultural Product Processing programs. Data were collected through pretest and posttest questionnaires measuring collaboration and communication skills, alongside observation sheets to monitor PBDL implementation. Statistical analysis using paired and independent sample t-tests revealed that students in the experimental group who received the PBDL treatment showed significantly greater improvement in both skills compared to those in the control group. The results support the hypotheses that PBDL is effective in enhancing interpersonal competencies, as it facilitates contextual, collaborative, and technology-enhanced learning experiences. The study concludes that integrating PBDL into vocational education is a strategic step toward preparing students for modern agro-industrial challenges. Practically, educators are encouraged to adopt PBDL with adequate digital infrastructure and teacher training, while theoretically, the findings contribute to the growing body of literature on constructivist and digitally mediated learning in vocational contexts.

Keywords: Collaboration Skill; Communication Skill; Project-Based Digital Learning; Vocational Learning; and Plantation and Herbal Commodities

INTRODUCTION

In the realm of vocational education, particularly in the Agribusiness of Agricultural Product Processing (AAPP) program, the competence of processing plantation and herbal commodities is of paramount importance (Chandra et al., 2019; Charatsari & Lioutas, 2019). This competence aligns not only with the objectives of technical and vocational education and training (TVET) but also with the global trend of sustainable development and the green economy (Chandra & Kumar, 2021; Morgan, 2010). Herbal and plantation-based products such as ginger, turmeric, lemongrass, and moringa have been increasingly recognized for their economic and therapeutic values, especially within the context of the growing wellness industry and community-based agribusiness (Ho et al., 2013; Nyamweru et al., 2024). Unfortunately, studies have shown that vocational students often lack sufficient technical mastery and entrepreneurial insight to optimize these local resources into marketable and sustainable products (Abawa, 2024). The lack of meaningful engagement in learning processes, coupled with traditional instructional strategies that rely heavily on rote practices and fragmented content delivery, limits students' ability to internalize these competencies effectively (Astuti et al., 2022; Nurtanto et al., 2021). If this problem persists, vocational education risks producing graduates who are technically underprepared and socially disconnected from the real-world challenges of agricultural innovation, which may eventually undermine the resilience of rural economies and the relevance of vocational training in the Fourth Industrial Revolution era.

At the root of these competency gaps lies a more profound pedagogical challenge, namely, the low level of interaction among students and between students and teachers during the learning process (Mutohhari et al., 2021). Numerous studies have highlighted that limited communication and collaboration in vocational classrooms contribute to disengaged learning, decreased motivation, and a lack of critical reflection on real-world problems (Kurniawan et al., 2021; Kurniawati et al., 2022; Tokan & Imakulata, 2019). Vocational students, particularly in AAPP programs, often experience learning as an isolated and procedural activity, devoid of meaningful social construction of knowledge or peer-to-peer synergy (Davoudi Kakhki et al., 2019; Yami et al., 2019). Moreover, the instructional methods employed tend to be teacher-centered, skill-drill-oriented, and lack contextually grounded innovation. Such instructional limitations hinder the actualization of 21st-century learning characteristics, including personalized,

contextualized, and technology-enhanced experiences (Kholifah et al., 2023; Mutohhari et al., 2021). Without innovation in pedagogy that facilitates meaningful, efficient, effective, and forward-looking competency acquisition, vocational education will struggle to remain relevant in preparing adaptive and collaborative workforces needed in the rapidly changing agro-industrial landscape.

Addressing these issues demands a strategic focus on developing two essential interpersonal skills: collaboration and communication. These skills are increasingly recognized as core components of holistic competence development in vocational contexts (Guo & Wang, 2021; Jaedun et al., 2024; Utami & Hitipeuw, 2019). Effective collaboration allows learners to share responsibilities, solve problems collectively, and appreciate diverse perspectives is an essential process in product development, especially in the agricultural product sector, where teamwork, coordination, and innovation are required (Leitão et al., 2024). Meanwhile, communication skills are crucial for articulating ideas, giving feedback, negotiating roles, and presenting solutions is a necessity when dealing with stakeholders, from farmers to customers (Masduki & Zakaria, 2020). However, building these skills remains a significant challenge. Research indicates that both students and teachers often operate within rigid curricular structures that do not promote active dialogue or co-construction of knowledge. In many vocational classrooms, students rarely engage in collaborative tasks that require sustained interaction or co-responsibility (Erarslan & Şeker, 2021; Järvelä et al., 2023). Additionally, school cultures and learning environments have not fully embraced interactive and learner- centered paradigms. Consequently, efforts to foster interpersonal skills such as collaboration and communication often fall short or remain peripheral in the learning process (Hardie et al., 2021).

To overcome these pedagogical challenges, a promising solution lies in implementing Project-Based Learning (PjBL) strategies that emphasize student-centered inquiry and real-world problem solving. Project-Based Learning provides a powerful framework to nurture communication and collaboration by placing students in authentic tasks where they must work together, negotiate meaning, and present their outcomes in various formats (Haryanto et al., 2021; Hernáiz-Pérez et al., 2021; Wan et al., 2020). Empirical studies have shown that PjBL improves students' ability to organize group efforts, express opinions clearly, and resolve conflicts constructively (Strevy, 2014; Surti et al., 2022). In the context of APHP, integrating PjBL allows students to process plantation and herbal products not only as technical tasks but also as opportunities for innovation, entrepreneurship, and community engagement. Further, the integration of digital technologies into project-based learning is referred to as Project-Based Digital Learning (PBDL)and has demonstrated added value in enhancing learning flexibility and interactivity (Prasetianto et al., 2024; Yasmin & Billah, 2023). By leveraging digital tools such as collaborative platforms, multimedia authoring tools, and online databases, PBDL facilitates broader engagement beyond the classroom. Students can interact with digital simulations, consult online agricultural resources, communicate with local herbalists or farmers via video conferencing, and document their findings through multimedia storytelling (Vinyals et al., 2023). This digital ecosystem enhances not only the accessibility and personalization of learning but also the authenticity of the projects, making learning more meaningful, efficient, and futuristic.

Thus, it becomes evident that fostering collaboration and communication skills through PBDL is not only a timely but also a strategic intervention to improve competency achievement in the processing of plantation and herbal commodities. The existing pedagogical limitations which is characterized by low student interaction, lack of innovation, and underdeveloped interpersonal skills can be addressed by situating learning within collaborative, real- world, and digitally enriched projects. Therefore, this study aims to investigate the effectiveness of project-based digital learning in enhancing vocational students' collaboration and communication skills, specifically in the subject of plantation and herbal commodities processing in the APHP program. By exploring how this pedagogical approach fosters both skills in meaningful and contextually relevant ways, this research contributes to the broader discourse on pedagogical innovation in green-oriented vocational education and its role in cultivating future-ready agro- entrepreneurs. Based on the theoretical framework in the explanations above, we propose two hypotheses as a means of testing the effectiveness of the treatment: (1) PBDL is effective in improving students' collaboration skills in the competency of processing plantation and herbal commodities; and (2) PBDL is effective in improving students' communication skills in the competency of processing plantation and herbal commodities.

METHOD

This study uses a quasi-experimental approach that aims to test the effectiveness of project-based digital learning (PBDL) in improving students' collaboration and communication skills in the competence of processing plantation and herbal commodities. In this case, two different groups already existed, so to anticipate bias in the data produced, we used a non-equivalent group quasi-experimental design adopted from Campbell & Stanley (1963). We consider this design because of its rationality, and the level of accuracy that can prevent bias in treatment and measurement results, because it is carried out without randomizing existing groups (Kohan et al., 2024). This research approach and design are translated into 5 main stages: identification and focus, implementation of the pretest, administration of treatment, implementation of the posttest, interpretation and conclusion. The study was conducted over a period of approximately four months, starting from the end of January to the end of May 2025. The treatment process took place in eight meetings according to the allocation of practical learning time in the competence of processing plantation and herbal commodities.

Four vocational high schools (VHS) were involved in this study, where all schools had two classes in the same current year with the same competencies taught. The selection of VHS was based on several considerations to ensure data accuracy without violating ethical procedures in the entire research process. First, the four schools are VHS majoring in agricultural product processing agribusiness (AAPP) which have met the standards of experience in organizing education and learning for more than five years, which is in accordance with that proposed by Zilic (2018). Second, the two classes in the AAPP major owned by each school teach plantation and herbal commodity processing competencies through the same teacher. Third, the availability of digital infrastructure and its accessibility are considerations to ensure that PBDL can be implemented by students and teachers. Finally, the partnership between the VHS majoring in AAPP and the herbal plantation agency is the main consideration to ensure the relevance of learning to actual work conditions (Rohm et al., 2021). A total of 108 students and 4 teachers were involved in a series of research processes which were divided into two control classes and two experimental classes. Before deciding on the involvement of all participants, we ensure their legality through adequate licensing procedures.

Throughout the study, we used several data collection techniques to ensure a high level of accuracy and meet the adequacy of data to answer the stated research objectives. At the pretest stage, we used a questionnaire on collaboration and communication skills to measure the initial abilities of both. This questionnaire is the basis for obtaining an initial picture and analyzing the equilibrium between groups (control and experiment) as a requirement for the non-equivalent group quasi-experimental design to be carried out. We also used a questionnaire to measure the value of collaboration and communication skills at the posttest stage. During the implementation of PBDL, we used observation techniques to observe and ensure the implementation of the stages and elements of PBDL in the competence of processing plantation and herbal commodities. Therefore, the data collection instruments that we used included a questionnaire on collaboration and communication skills, and an observation sheet for the implementation of PBDL. Table 1 explains in detail the blueprint for both instruments in this study.

Table 1. Blueprint of research instruments

Instrument	Indicator	Operational
Collaboration skill questionnaire	Team goal orientation	Ability to understand, plan, and work towards common goals with other team members.

(Järvelä et al., 2023)	Shared responsibility & accountability	Ability to take responsibility for group tasks, share the workload fairly, and complete tasks together with commitment.
	Conflict resolution & problem-solving	Ability to manage differences of opinion, resolve conflicts constructively, and find solutions in the context of a work team.
	Role flexibility and support	Ability to adapt roles within the team as needed and provide active support to other members.
Communication skill questionnaire (Stehle & Peters-Burton, 2019)	Active listening	Ability to listen fully, understand the information conveyed by others, and respond appropriately.
	Clarity & Coherence in verbal expression	Ability to convey information, instructions, and ideas logically and efficiently in a work or learning context.
	Written communication skills	Ability to write reports, work instructions, and technical documentation systematically, accurately, and professionally.
PBDL implementation observation sheet (Haryanto et al., 2021; Sudira et al., 2022)	Problem orientation	Asking questions about contextual issues or problems using digital technology
	Project planning & design	Designing projects, defining learning objectives, assigning roles, and developing work plans and project schedules collaboratively.
	Investigation & exploration	Conduct in-depth exploration and data/information collection through digital sources, observations, or online interviews.
	Project development	Develop solutions/prototypes/project works assisted by digital tools.
	Collaboration & communication	Share progress and work results among team members, including teachers and experts.
	Reflection & feedback	Evaluate the learning process, obstacles faced, and self and team evaluation, both individually and collectively.

The collected data were analyzed using t-test with two different specific methods. First, to test the effectiveness of PBDL in improving collaboration and communication skills, it is necessary to look at the trend of differences in the average pretest-posttest scores in each class, both in the experimental class and the control class. In this case, the paired sample t-test is the most appropriate method in terms of accuracy and suitability of the results. In addition, the normality that is met in the data provides an opportunity for this testing method to be used more rationally (Reid, 2014). After seeing the trend of the differences, the independent sample t-test is then used to test the difference in the average posttest scores of collaboration and communication skills between the experimental class and the control class. The provision is, if the significance value (p) is below or equal to a significance level of 5% ($p \leq 0.050$), which indicates that the experimental class has a higher average value, then the hypothesis is accepted, or in other words there is a difference in the average posttest score between the two classes. The homogeneity standard that is met provides an opportunity for this testing method to be carried out (Johnson & Wichern, 2007).

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RESULT AND DISCUSSION

Analysis Prerequisite Test

Prerequisite analysis test was conducted to determine whether the data were normally distributed and had homogeneous variance as a requirement to perform paired sample t-test and independent sample t-test. The analysis prerequisite test contains tests for data normality and homogeneity of variance. The analysis prerequisite test was carried out using SPSS V 21 software. The results of the data normality test are shown in table 2 below.

Table 2. Normality test result

Variable	Pre-test p Value		Decision	Post-test p Value		Decision
	Experiment	Control		Experiment	Control	
Collaboration skill	0,215	0,119	Normal	0,184	0,262	Normal
Communication skill	0,281	0,108	Normal	0,314	0,264	Normal

Based on the results of the data normality test using the Kolmogorov Smirnov formula, the significance value in each class was greater than 0.050 at a significance level of 5%, so it can be concluded that the data is normally distributed. After the data is known to be normally distributed, then the homogeneity of variance test is then carried out. Based on the results of the homogeneity of variance test, it is known that the significance value for all variables is greater than 0.050 at a significance level of 5%, so it can be concluded that the variance of the experimental class posttest data and control class posttest data on the collaboration and communication skill variables is the same or homogeneous. The results of the homogeneity test are shown in table 3 below.

Table 3. Homogeneity Test Results

Variable	Df1	Df2	Sig	Dec.
Collaboration skill	1	106	0,155	Homogeneous
Communication skill	1	106	0,267	Homogeneous

The Effectiveness of Project-Based Digital Learning in Improving Collaboration and Communication Skill

Before assessing the effectiveness of the Project-Based Digital Learning (PBDL) model in improving students' collaboration and communication skills through inferential statistical analysis using t-tests, it was essential to first conduct an initial equivalence test on both skill variables between the experimental and control groups. This preliminary step aimed to ensure that both groups had comparable levels of initial ability prior to the implementation of the intervention, thereby allowing any subsequent differences in outcomes to be more confidently attributed to the PBDL treatment rather than to pre-existing disparities. The equivalence test was carried out using an independent sample t-test, which is a commonly used method to compare the means of two separate groups. The results of this analysis indicated that the significance values for both collaboration and communication skills were greater than 0.05, suggesting that there were no statistically significant differences in the pretest scores between the experimental and control classes. These findings confirm that the two groups were balanced in terms of their initial skill levels, which validates the appropriateness of proceeding with the effectiveness testing phase. The confirmation of this baseline equivalence is critical in quasi-experimental designs, especially those employing non-randomized groups, as it helps to ensure the internal validity of the study. The detailed results of the equivalence test, including the degrees of freedom, mean scores, t-values, and significance levels, are presented in Table 4 of the findings section.

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Table 4. Initial Ability Test Result

Variable	Experiment		Control		t Value	Sig	Decision
	Df	Mean	Df	Mean			
Collaboration skill	52	21,84	52	21,10	1,108	0,254	Balanced
Communication skill	52	21.16	52	21.00	0,983	0,307	Balanced

Following the completion of the initial ability testing, the next crucial step in the research process was the implementation of the Project-Based Digital Learning (PBDL) model as an instructional treatment for the experimental class. In contrast, the control class continued to use the conventional instructional model that had been previously in place. This treatment phase was carried out over a series of eight structured sessions, each aligned with the practical learning schedule allocated for the subject of plantation and herbal commodities processing. Within the PBDL framework, students participated in a hands-on project aimed at developing functional food or beverage products derived from locally available herbal ingredients, including ginger, lemongrass, turmeric, and moringa leaves. The production process was comprehensive and contextually grounded, involving several critical phases including market needs analysis, formulation of recipes, hygienic processing techniques, and eco-friendly packaging design. Additionally, students integrated various digital tools and platforms throughout the learning process. For instance, documenting their progress using digital media, simulating promotional campaigns through social media platforms, and delivering final project presentations in multimedia formats such as videos or infographics. As a result, students not only produced tangible, consumable products but also created digital portfolios that showcased both their technical competencies and interpersonal skills. To quantitatively assess the impact of this treatment, a paired sample t-test was conducted to measure the difference in mean scores between the pretest and posttest results for collaboration and communication skills within each group. The outcomes of this paired sample t-test are comprehensively presented in Table 5 and serve as the basis for evaluating the significance of improvement observed in the experimental class following the PBDL intervention.

Table 5. Paired Sample t-Test Result

Variable	Pre. – Post. Experiment			Pre. – Post Control		
	Mean Diff.	t Value	Sig	Mean Diff.	t Value	Sig
Collaboration skill	-15,664	-10,184	0,000	-6,002	-4,058	0,000
Communication skill	-14,981	-9,294	0,000	-4,322	-3.703	0,000

Based on the results of the paired sample t-test, the significance values for the pretest-posttest pairs in the experimental class for both collaboration and communication skills were 0.000 ($p \leq 0.05$), indicating a statistically significant improvement in students' abilities after receiving the Project-Based Digital Learning (PBDL) treatment. This outcome confirms that the implementation of PBDL had a meaningful and positive effect on enhancing these interpersonal skills, thereby supporting the first research hypothesis. Following the confirmation of significant within- group improvement, an independent sample t-test was conducted to compare the posttest mean scores between the experimental class and the control class. This analysis aimed to determine whether the observed improvements in the experimental group were significantly greater than those in the control group, with detailed results presented in Table 6 below.

Table 6. Independent Sample t-Test Result

Variable	Mean difference	t Value	Sig.
Collaboration skill	9,662	7,283	0,000
Communication skill	10,659	8,002	0,000

Based on the results of the independent sample t-test, the significance values for both collaboration and communication skills were found to be 0.000 ($p \leq 0.05$), indicating a statistically significant difference in the mean scores between the experimental class, which received the Project-Based Digital Learning (PBDL) treatment, and the control class, which did not. These results confirm that students in the experimental group outperformed those in the control group in both skill areas following the intervention. The significantly higher average scores in the experimental class demonstrate the effectiveness of the PBDL model in fostering students' interpersonal competencies, thus providing empirical support for the second hypothesis of the study.

DISCUSSION

The findings of the study demonstrate that the Project-Based Digital Learning (PBDL) model significantly enhances students' collaboration and communication skills within the competence of processing plantation and herbal commodities. Results from paired and independent t-tests reveal substantial improvements in the pretest-posttest scores of students in the experimental group compared to those in the control group. These findings highlight the effectiveness of a digitally integrated project-based approach in fostering participatory, interactive, and meaningful learning experiences, particularly in vocational education contexts that have long been critiqued for their conventional, teacher-centered instructional methods. Pedagogically, this can be rationalized through Vygotsky's social constructivist theory, which emphasizes the importance of social interaction and technological mediation in the development of cognitive and social capabilities. In this learning environment, PBDL facilitates collaborative learning, joint knowledge construction, and the development of communication skills through teamwork and the use of digital media (Ngereja et al., 2020; Rahman et al., 2022).

Despite its evident benefits, PBDL is not without its criticisms. Prior research has indicated that the success of PBDL heavily depends on teacher readiness, student learning culture, and the availability of adequate digital infrastructure (Basilotta Gómez-Pablos et al., 2017; Nurdiansah et al., 2021). In some cases, as reported by (Bell (2010); Lizunkov et al. (2020), the approach may present challenges if students lack sufficient digital literacy or time management skills. Moreover, hierarchical and teacher-dominated learning cultures prevalent in many vocational institutions may hinder the optimal implementation of project-based strategies. Zheng et al. (2021) found that collaboration and communication in learning are significantly influenced by teacher autonomy and a curriculum structure that supports active learning. Therefore, while the current findings support the effectiveness of PBDL, it is important to consider contextual factors that may affect the sustainability of its impact.

From a supportive perspective, this study aligns with recent evidence suggesting that collaboration skills in 21st-century learning involve not only teamwork but also socially shared regulation, allowing learners to manage their collaborative and communicative processes metacognitively (Järvelä et al., 2023). Additionally, the integration of digital technologies has been shown to enhance accessibility and broaden student engagement, as highlighted by Crespí et al. (2022); Nilsook et al. (2021); Wahyudi & Winanto (2018). In agribusiness education, PBDL offers a highly relevant learning model by engaging students directly in managing the production and marketing processes of local herbal commodities, from project planning and problem exploration to digital communication of outcomes. Thus, learning extends beyond technical knowledge transfer to include the development of entrepreneurial mindsets and interpersonal competencies essential in the modern agro-industrial workforce. These benefits support the growing demand for green skills and competencies within the framework of TVET for Sustainable Development (Sidik & Pratama, 2019; Sudjimat et al., 2020).

The implications of this study are both practical and theoretical. On the practical level, it encourages vocational education institutions to adopt project-based digital learning as a core strategy for developing students' interpersonal skills, especially collaboration and communication. This model should not be seen as a one-time intervention but integrated into the core curriculum, supported by institutional policies, teacher training, and digital infrastructure. On the theoretical side, the study contributes to the body of empirical evidence on the effectiveness of digital constructivist pedagogy in agribusiness-based vocational learning and enriches the discourse on how 21st-century skills can be developed contextually and sustainably. Future research is advised to explore the integration of PBDL with other pedagogical approaches such as STEM or inquiry-based learning and to extend the scope of skills measured to include critical thinking, creativity, and problem-solving. Further studies might also test the model's effectiveness across various vocational fields and socio-economic contexts to better understand the generalizability and sustainability of its impacts.

CONCLUSION

This study concludes that Project-Based Digital Learning (PBDL) is an effective instructional model for enhancing vocational students' collaboration and communication skills, particularly in the context of processing plantation and herbal commodities. The findings, supported by both paired and independent sample t-tests, reveal a significant increase in students' interpersonal skills in the experimental group compared to the control group. PBDL enabled students to engage in authentic, context-driven, and digitally supported learning experiences that promoted teamwork, problem-solving, and idea articulation. These outcomes reinforce the importance of integrating constructivist, student-centered approaches in vocational education to prepare learners for complex, real-world challenges in agro-industry sectors. However, this study is not without limitations. It was limited to four schools within a specific program and context, which may affect the generalizability of the findings. Furthermore, variations in digital infrastructure and teacher readiness may influence the scalability of PBDL. Therefore, future studies are recommended to explore the long-term impact of PBDL across diverse vocational fields and to integrate other 21st-century skills such as critical thinking and creativity. Practically, schools should invest in digital tools and teacher training, while theoretically, this research contributes to the discourse on effective digital pedagogies that align with green skills development and sustainable vocational education transformation.

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